RT5
Life Cycle Systems Engineering Needs for Evolutionary Acquisition

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Principal Investigator: JoAnn Lane, University of Southern California

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Summary of RT 5 SoS SE Activities and Future Recommendations

Prepared by Dr. Jo Ann Lane, RT 5 SoS SE Principal Investigator

Introduction

This report summarizes the system of systems (SoS) systems engineering (SE) technical activities performed under the Systems Engineering Research Center (SERC) RT 5 task from August 2009 through October 2010. In addition, recommendations for future SoS SE research are provided.

SoS SE Activities Performed

The following sections identify the SoS SE activities performed within the indicated month.

August 2009

SoS process research activities performed during this period include: analysis of SoS processes with respect to lean principles, analysis of modeling and simulation (M&S) applications for SoS processes based upon responses to a recent National Defense Industrial Association (NDIA) M&S survey, and SoS artifact analysis to support further guidance to SoS programs with respect to content and form of key process artifacts.

September 2009

Continued analysis of SoS processes with respect to lean principles, analysis of M&S applications for SoS processes based upon responses to a recent National Defense Industrial Association (NDIA) M&S survey, and SoS artifact analysis to support further guidance to SoS programs with respect to content and form of key process artifacts. Began development of a generic SoS case study to support analyses and presentation of SoS research findings at conferences and workshops.

October 2009

Continued analysis of SoS processes with respect to lean principles, analysis of M&S applications for SoS processes based upon responses to a recent NDIA M&S survey, and SoS artifact analysis to support further guidance to SoS programs with respect to content and form of key process artifacts. Attended NDIA Systems Engineering conference in San Diego, CA and presented the results of the M&S survey and the use of SysML to characterize and model SoSs. Continued development of a generic SoS case study to support analyses and presentation of SoS research findings at conferences and workshops. (This model is now referred to as the USC SoS Reference Model and is being used by OSD, USC, and MIT to further the understanding of SoSE.) Collaborated with MIT Lean Advancement Initiative representatives to develop an IEEE Systems extended abstract on how to accelerate the understanding and optimization of SoSE through lean enterprise principles.

November 2009

Continued analysis of SoS processes with respect to lean principles, analysis of SoS M&S applications based upon responses to a recent NDIA M&S survey and in support of evolutionary acquisition of cross-cutting capabilities, and SoS artifact analysis to support further guidance to SoS programs with respect to content and form of key process artifacts. Continued development of a generic SoS case study to support analyses and presentation of SoS research findings at conferences and workshops. Continued collaboration with MIT Lean Advancement Initiative representatives on how to accelerate the understanding and optimization of SoSE through lean enterprise principles.

Attended USC COCOMO Forum hosted by MIT the week of November 2nd and met with several MIT researchers working in the SoS arena. Key side meetings were with Prof. Joseph Sussman, Tsoline Mikaelian, and Chris Roberts. Most of the SoS topics discussed in these meetings were focused on SoS in the transportation domain, SoS organizational and management research, SoS cost modeling and SoS decision theory. In addition, met with Ray Madachy from NPS to discuss extensions to SoS system dynamics cost model to incorporate features to evaluate capability change rate and SoS quality factors.

December 2009

Continued analysis of SoS processes with respect to lean principles and SoS artifact analysis to support further guidance to SoS programs with respect to content and form of key process artifacts. Continued development of SoS Reference Model to support analyses and presentation of SoS research findings at conferences and workshops. Continued collaboration with MIT Lean Advancement Initiative representatives on how to accelerate the understanding and optimization of SoSE through lean enterprise principles.

January 2010

Continue analysis of SoS processes with respect to SoS artifact analysis, SoS test and evaluation, development of the SoS Reference Model, and development of extensions to SoS system dynamics model to evaluate the impact of capability change rates and quality factors related to the level of SoS engineering activities.

February 2010

Continued analysis of SoS processes with respect to SoS artifact analysis to support further guidance to SoS programs with respect to content and form of key process artifacts. Continued development of SoS and SoSE library to support SoSE research and analysis. Provided inputs to IEEE SoSE paper on SoS test and evaluation.

March 2010

Continued analysis of SoS processes with respect to SoS artifact and SoS test and evaluation. Finalized SoS test and evaluation paper for submission to IEEE SoSE 2010 conference. Updated the MITRE SoS and SoSE SharePoint library to support SoSE research and analysis. Provided inputs to IEEE SoSE paper on SoS test and evaluation. Developed a plan for SoSE artifact journal paper and survey form to capture additional artifact information for paper. Conducted a literature review in response to Mr. Steve Welby's SoS SE questions. Attended the NIDA Test and Evaluation conference in San Diego, CA and provided a

summary of sessions attended to DDR&E SoS SE team. Attended the USC Center for Systems and Software Engineering Annual Research Review (ARR), provided an overview of on-going SoSE research, participated in the MIT/USC PATFrame workshop on unmanned autonomous SoS test and evaluation, and provided summary of SoS-related information presented at the conference to the DDR&E SoS SE team.

April 2010

Continued analysis of SoS processes with respect to SoS artifact and SoS test and evaluation. Provided additional inputs to IEEE SoSE paper and presentation on SoS test and evaluation. Continued to develop the plan for SoSE artifact journal paper and survey form to capture additional artifact information for paper and began mining SoS SE guidebook pilot interview notes for detailed artifact data. Began review of SoS SE guidebook pilot interview notes for data related to Mr. Steve Welby's SoS SE questions. Attended IEEE Systems 2010 Conference in San Diego, CA and presented a paper that analyzed SoS SE activities with respect to lean enterprise principles. Provided a summary of sessions attended to DDR&E SoS SE team. Provided inputs and attended US-Australian SoS telecon on 4/12/2010. Attended Army ATEC briefing at the SoS T&E telecon on 4/13/2010. Attended the NDIA SoS SE telecon on 4/20/2010. Presented "SysML Strategies to Characterize and Analyze Systems of Systems" at the SoS Collaborator's meeting on 4/27/2010.

May 2010

Attended the International Conference on Software Engineering (ICSE) from May 4- 7, 2010. Presented Incremental Commitment Model implications and support for system of systems engineering and contrasted it to other system development special cases. Continued analysis of SoS processes with respect to SoS artifact and SoS test and evaluation and discussed findings at SoS SE telecons led by Dr. Judith Dahmann. Provided final inputs to IEEE SoSE paper on SoS test and evaluation. Continued collection of information for SoSE artifact journal paper, primarily by mining SoS SE guidebook pilot interview notes for detailed artifact data. Continued review of SoS SE guidebook pilot interview notes for data related to Mr. Steve Welby's SoS SE questions. Presented talk on SoSs, what they are and how to engineer them at the San Diego INCOSE Chapter meeting on 5/24/2010. Attended SoS Collaborator's meeting on 5/25/2010 that discusses SoS interoperability challenges and approaches. Prepared and submitted abstracts on SoSE research for consideration at the NDIA 2010 conference.

June 2010

Continued analysis of SoS processes with respect to SoS artifact and SoS test and evaluation and discussed findings at SoS SE telecons led by Dr. Judith Dahmann. Set up a wiki site at USC to collect, share, and collaborate with other SoSE researchers on the development of the Regional Area Crisis Management SoS (RACRS) reference SoS and associated example engineering artifacts. Began work on RACRS example CONOPS by evaluating various CONOPS outlines and tailoring one to fit SoS situation. Continued collection of information for SoSE artifact journal paper, primarily by mining SoS SE guidebook pilot interview notes for detailed artifact data. Continued review of SoS SE guidebook pilot interview notes for data related to Mr. Steve Welby's SoS SE questions. Finalized plans to attend the International Conference on Software Processes in Paderborn, Germany and the INCOSE Symposium in

Chicago. Provided copies of papers to be presented for SERC review and approval (Critical Success Factors for Rapid, Innovative Solutions; Evidenced-Based Software Processes; and Architected Agile Solutions for Software-Reliant Systems). Had follow-up discussions with May SoS Collaborator speaker on SoS interoperability challenges and approaches to better understand findings and scope of data collection. Attended SoS Collaborator's presentation by Stephan Blanchette on 6/8/2010. Prepared and submitted abstracts on SoSE research for consideration at the NDIA 2010 conference.

July 2010

Continued analysis of SoS processes with respect to SoS artifact and SoS test and evaluation and discussed findings at SoS SE telecons led by Dr. Judith Dahmann. Notified other SoS researchers about the USC RACRS wiki site to collect, share, and collaborate with other SoSE researchers on the development of the RACRS reference SoS and associated example engineering artifacts. Continued work on RACRS example CONOPS by evaluating various CONOPS outlines and tailoring one to fit SoS situation. Continued collection of information for SoSE artifact journal paper, primarily by mining SoS SE guidebook pilot interview notes for detailed artifact data. Continued review of SoS SE guidebook pilot interview notes for data related to Mr. Steve Welby's SoS SE questions. Attended the International Conference on Software Processes in Paderborn, Germany and the INCOSE Symposium in Chicago. Presented "Accelerating System of Systems Engineering Understanding and Optimization through Lean Enterprise Principles" at the July DoD SoS Collaborator's biweekly telecon. Prepared and submitted a paper titled "Using Models to Understand and Evolve SoSs" for consideration at the International Congress on Ultra Modern Telecommunications and Control Systems, Special Session on System of Systems conference after SERC approval.

August 2010

Attended and participated in the NDIA SoS T&E Collaborative Workshop on August 17, 2010 at the MITRE facilities in McLean, VA. Worked with the MITRE SoS SE team to develop report on workshop. Worked with SoS SE team to elaborate SoS SE artifacts for various presentations and a journal article. Attended and participated in the PATFrame Workshop held August 23-25, 2010 at MIT in Boston, MA.

September 2010

Finalized SoS artifacts presentation for the NDIA SE 2010 conference and submitted it to the SERC review/approval process. Participated in SoS SE teleconferences to review the SoS SE IEEE Systems 2011 abstract on "Implementation View of Systems Engineering for Systems of System" and to refine briefing for Mr. Steve Welby in response to his SoS SE questions. Began update of RT 5 Technical and Management Work Plan (A009) to reflect Option Year 2 activities. Began work on SoS Processes final report (A008).

October 2010

Finalized and delivered RT 5 Technical and Management Work Plan (A009) to reflect Option Year 2 activities. Reviewed and provided comments on two SoS SE guidebook synopses. Finalized and delivered SoS Processes final report (A008).

Attended NDIA SE 2010 conference and presented RT 5 research on "Key System of Systems Engineering Artifacts to Guide Engineering Activities". Also attended various other SoS-related presentations during the week.

Recommendations for Future SoS SE Research

The following recommendations for future SoS SE research are based upon technical guidance requested at conferences and workshops by those responsible for the management and evolution of SoSs or identified as key SoS SE key challenges in conference papers and/or technical reports. Also note that while each of these research areas can be independently pursued, there is considerable overlap in several areas.

1. **Better acquisition approaches and processes for SoS capabilities:** Many SoSs are not acquisition programs (or programs of record), but are "umbrella" programs that incorporate multiple systems that are in various stages of acquisition with the goal of providing cross-cutting SoS capabilities. SoS challenges related to current acquisition processes are SoS authority to guide the evolution of the SoS as well as funding to support SoS initiatives and testing at the SoS level. In addition, without a clear understanding of which new programs are to participate in which SoSs, the associated interoperability requirements, and potential conflicts, there are often missed opportunities to improve or provide additional SoS capabilities. While it may not be desirable to always manage SoSs as programs of record, SoS SE research in this area could investigate alternatives to improve the current ad hoc process.
2. **Improved SoS test and evaluation methods, processes, and tools:** Much of the testing at the SoS level depends upon opportunities to influence single system test events, to conduct tests during various exercises, and to collect operational data at various points in time. This testing strategy can limit the ability of the SoS engineers to understand SoS limits and to probe for undesirable emergent behaviors. SoS SE research in this area can identify improved test and evaluation methods, processes, and tools that strengthen the ability of the SoS engineering teams to test SoS capabilities, understand their performance with respect to the associated objectives, identify and mitigate potential undesirable emergent behaviors, and instrument constituent systems to better support SoS test efforts.
3. **Maturation of cost models to support the SoS SE:** Initial parametric cost model research for software development and systems engineering has led to several commercial cost models and continues to support the evolution of these cost models. These cost models use a set of parameters that characterize the engineering product, the processes used to develop the product, and the skills and experience levels of the technical staff responsible for the development of the product. However, as systems are being integrated into one or more net-centric system of systems (NCSoS) and single system capabilities are being integrated to support one or more NCSoS capabilities, it has become necessary to develop processes and tools to evaluate the costs of various approaches for providing these more complex, cross-cutting SoS capabilities. Initial work has led to a relatively solid system of systems engineering (SoSE) cost model framework that is based Department of Defense (DoD) case studies of SoSE processes [1]

and on previous software and systems engineering cost models for single systems. The next steps are to collect data from a selected set of pilot SoS(s) to better understand the predictive ability of this SoSE cost model framework as well as to further expand the current cost model. Suggested research includes analysis and refinement of the existing SoS SE cost model, analysis to better understand and capture the impacts of interoperability characteristics and constraints on SoSE costs, and development of extensions to evaluate SoS total cost of ownership and incorporate incremental productivity decline factors as an SoS becomes larger and more complex.